Fenestrated Aortic Stent Grafts

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ABSTRACT

Fenestrated stent grafts have been developed to offer an endovascular treatment option to those patients with abdominal aortic aneurysms whose infrarenal necks are anatomically unsuitable for endovascular repair with standard infrarenal devices. The ability to have customized fenestrations that will preserve flow to essential visceral arteries allows proximal seal and fixation to be achieved at and above the renal level. This article discusses patient selection, stent-graft design, and the importance of accurate planning. Deployment techniques along with complications and their avoidance are considered. The published midterm results are reviewed and appear to justify the continued use and evaluation of this technique as an alternative to open surgical repair in high-risk patients with infrarenal necks unsuitable for standard endovascular repair.

KEYWORDS: Fenestrated endovascular aneurysm repair

Objectives: Upon completion of this article, the reader should understand the indications for considering patients with abdominal aortic aneurysm for a fenestrated endovascular repair.

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The infrarenal aortic neck is the key anatomical area in the success or failure during endovascular repair of abdominal aortic aneurysms. Endovascular repair for short-necked aneurysms with standard devices is associated with an increased risk of proximal type 1 endoleak.^{1,2} Standard devices should not be used in the treatment of juxtarenal aneurysms. The rates of operative mortality and morbidity associated with elective open repair of juxtarenal aneurysms are higher than those for open repair of infrarenal aneurysms.^{3–5} The need for suprarenal or supraceliac aortic clamping is responsible for these poorer outcomes from open repair. The possibility of an entirely endovascular repair for these patients is therefore attractive.

The first report of the use of fenestrated grafts was in 1999⁶ less than a decade after Parodi's seminal report on the use of an endograft for the repair of an abdominal

aortic aneurysm.⁷ The speed of evolution of fenestrated graft technology reflects the early desire to move the seal zone higher in the aorta to the more stable visceral segment in patients with short or absent aortic necks. Fenestrated grafts are individually customized devices based on precise plans of the location of the visceral arteries from computed tomography (CT) datasets. The deployment of fenestrated grafts must be equally precise and is more complex than the deployment of standard endografts. The incorporation of the visceral arteries in the repair generates specific complications from the procedure.

This article considers the design of fenestrated grafts and the selection criteria for their use. We also discuss the planning and deployment of fenestrated grafts and specific device-related complications. The published literature in this area is also summarized.

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DEVICE DESCRIPTION

The only commercially available CE-marked fenestrated graft is made by Cook (Bloomington, IN) and based on the Zenith platform. Zenith endografts are composed of woven polyester fabric and Gianturco stainless-steel stents. The Zenith abdominal endovascular graft is a bifurcated stent graft and incorporates a bare metal anchor stent proximally that is barbed for device fixation. The stent below this is the sealing stent, which is positioned just below the renal arteries in the infrarenal aortic neck.

The abdominal fenestrated graft has a composite body with an individually customized proximal body and an off-the-shelf distal bifurcated body and iliac limb components. The proximal body typically contains from one to four fenestrations for preservation of flow to the

renal arteries, superior mesenteric artery (SMA) and celiac axis. The proximal fenestrated component is tubular, and it may continue to be rotated after partial deployment because the anchor stent remains sheathed in a top cap and also because diameter-reducing ties posteriorly are not released until after the visceral arteries have been successfully accessed. This capacity for adjustment until the moment of final deployment allows for precise vertical and circumferential positioning of the fenestrations.

A range of available fenestrations include a scallop at the level of the top of the fabric and small and large fenestrations below this level (Table 1). There are manufacturing limitations to the height, width and vertical positioning of fenestrations based on the design of the Gianturco stents into which or between which the fenestrations must be positioned. A scallop describes a

Table 1 Fenestration Options

Fenestration	Description	Use	Image*
Scallop	Depth, 6–12 mm Width, 10 mm Fit between stent struts	For superior mesenteric artery (SMA) when small fenestrations are used for renal arteries Single low renal artery May be stented
Small	Width, 6 mm Height, 6–8 mm Distance from proximal edge must be ≥ 15 mm Fit between stent struts	May be stented
Large	Diameter, 8–12 mm Distance from proximal edge must be ≥ 10 mm Stent struts may cross	For SMA when renal arteries and SMA are close together Accessory renal arteries Not stented

*Note gold radiopaque markers around edges of fenestration.

U-shaped gap in the proximal fabric of the graft. Small and large fenestrations are either circular or elliptical and placed below the proximal fabric margin. Scallops and small fenestrations typically have no struts across them and therefore may be stented to help maintain their alignment and resist longitudinal as well as rotational migration. Large fenestrations typically have a stent strut running across them and are therefore not intended to be stented.

The commonest design has two small fenestrations for the renal arteries and a scallop for the SMA. The next most common graft design incorporates a single scallop to preserve flow to the lowermost of asymmetrically positioned renal arteries.

Small fenestrations for the renal arteries are typically 6 mm in diameter and either 6 or 8 mm in height. These are intended to be stented after release to prevent shuttering of the renal arteries due to misalignment either initially or during the evolution of the aneurysm because of circumferential or vertical movement of the fenestration.

The first generation of fenestrated grafts incorporated fenestrations without any reinforcement of their margins. A more recent development has been the use of nitinol ring reinforcement of the fenestration. These are particularly useful when covered renal stents are needed in the treatment of juxtarenal aneurysms because the covered stent may be dilated and locked against the nitinol ring to create a seal.

Balloon expandable stents are used and these should be of closed cell design to open against the fenestration and resist any shear forces that may be encountered at the interface between the fenestration and the renal stent. The choice of stent is important and the demands on adjunctive renal stents are different to those placed on stents for stenotic disease. Increasingly manufacturers are designing lower profile, flexible and trackable stents for renal artery stenosis. The flexibility and trackability usually comes from reducing the connectivity of the stent design to an open cell format with a reduction in the connections between the struts and less overall metal. These design properties are not ideal for adjunctive stent use in fenestrated endografts.

Accurate rotational alignment is permitted by the fluoroscopic visualization of radiopaque markers. There is a check mark anteriorly on the endograft to confirm that the orientation is correct. More subtle rotational alignment is aided by three vertical anterior markers and three horizontal posterior markers that form a cross on the fluoroscopic image when correctly oriented. Scallop/fenestration markers are also incorporated at the margins of each fenestration (Fig. 1). The distal component of the composite body is bifurcated and designed to have a generous overlap with the proximal component. The iliac limb extensions are placed in the normal way, completing a fenestrated composite-body bifurcated endograft.

Figure 1 Intraprocedural image with partial deployment of the proximal component of a fenestrated graft. Sheaths and stents are positioned in both renal arteries and the superior mesenteric artery. The anterior check mark, overlapping vertical anterior and horizontal posterior markers, and the marginal fenestration markers are shown.

PATIENT SELECTION

The UK-EVAR (Endovascular Aneurysm Repair) 2 trial results did not show a benefit from the use of standard endovascular grafts in patients deemed to be unfit for open repair of infrarenal aneurysms.⁸ It is logical that the more complex procedure of f-EVAR (fenestrated endovascular aneurysm repair) is similarly unlikely to benefit medically unfit patients. There are long-term uncertainties about the use of fenestrated endografts, particularly with regard to the increased modularity and the patency of visceral artery stents. Because of these concerns, we currently reserve f-EVAR for informed patients who have anatomically suitable aneurysms but who are deemed to be at higher than normal risk from open repair. Patients who are medically very unfit and cannot be improved by medical therapy or who have limited life expectancy are unlikely to benefit from repair.

The anatomical suitability is assessed using a CT dataset. Our threshold for treatment is an aneurysm diameter of 5.5 cm, based on the results of the UK small aneurysm trial.⁹

The required neck length for endovascular treatment with standard, nonfenestrated devices is 15 mm. This figure has generally been accepted both in the medical literature and in the "instructions for use" of most endovascular devices. Several studies have reported that a short infrarenal neck is a significant factor in the development of proximal type 1 endoleak.^{1,2}

Few operators treat neck lengths of < 10 mm with a standard device; however, there is a gray area in this context with regard to aneurysms with borderline necks

of between 10 and 15 mm. Some operators opt for a well-placed standard device if there are no other adverse features in the aortic neck; other operators prefer to move the sealing point higher with a fenestrated graft.

The aortic neck angle, defined as the angle between the longitudinal axis of the aortic neck and the aneurysm sac, is an important consideration for two reasons. First, the deployment of a fenestrated graft requires the precise positioning of the endograft and the ability to reposition the graft after partial deployment. This facility to reposition the device is compromised with adverse neck angles. The second issue relates to device planning. Determining how the endograft will lie after release in a markedly angulated neck is problematic, and it is thus difficult to calculate the required separation of the visceral fenestrations of a multifenestrated graft. The instructions for use of the Cook fenestrated graft state that fenestrated grafts are intended for aneurysms with a neck angle of <45 degrees.¹⁰

Severe aortic atheroma at the level of the visceral arteries is an important adverse feature because the manipulation of the endografts, catheters, and stents at this level may cause microembolization. In our series of 46 patients we have had one death from multiorgan failure due to microembolization and we now consider significant atherothrombosis at the level of the visceral arteries to be a contraindication to fenestrated endografts.

The delivery sheath of the proximal component typically has an external diameter of 22 or 24 F, and the iliac artery must be of suitable quality to accept such a system. The device must not only be delivered, but the operator must also be able to rotate it afterward. Small and calcified external iliac arteries are a relative contraindication to transfemoral device delivery, and endovascular repair in such anatomy may require a retroperitoneal iliac conduit. Because these devices are “made to meas-

ure” based on CT anatomy, patients with symptomatic aneurysms requiring urgent repair cannot be considered for fenestrated repair.

Like others, the authors have also treated type I proximal endoleaks with short necks, following previous endovascular repair with an infrarenal device, as well as juxtarenal proximal para-anastomotic aneurysms following open surgical repair, using fenestrated stent grafts.^{11–13} Fenestrated stent grafts extend the range of possible endovascular solutions for these complications as an alternative to open surgical repair.

PLANNING

One of the principal objectives of the procedure is to ensure a stable position of the proximal endograft, allowing for endovascular seal, resistance to migration, and the preservation of flow to important aortic side branches. Planning fenestrated grafts requires a thorough understanding of the design of the endograft and the ability to use a vascular workstation.

The vertical and circumferential position of the celiac axis and the superior mesenteric and renal arteries must be determined from a high-quality multislice CT dataset with slice thickness of 2 mm or less. The height difference is measured on reconstructed images corrected for craniocaudal and lateral angulation (Fig. 2A,B). This calculation can be difficult in severely angled necks, which should not be considered for this procedure. The circumferential position is related to the clock face recorded to the quarter hour. The diameter at the level of seal is measured so the diameter of the sealing stent may be chosen.

The design of the Zenith graft involves a barbed anchor stent to which the top of the fabric is attached. The stent below this is the high radial force sealing stent. For most graft diameters, the sealing stent is 17 mm in

Figure 2 (A,B) Multiplanar reformatted computed tomography images showing the interrenal separation. The axial distance between the renal arteries is 4.5 mm. The true distance is 8 mm correcting for lateral angulation and anticipating the lie of the stent graft after deployment.

height. In some of the larger grafts, the sealing stent may be 21 mm in height. There is 4 mm of fabric above the top of the sealing stent, which is attached to the bottom of the anchor stent. It is desirable to place most, if not all, of the sealing stent in the aortic neck to ensure long-term stability. If one knows the diameter of graft required and defines where the neck begins, then it is possible to determine the required position of the sealing stent and thus which vessels will be covered by a stent in this position. The next phase of planning is to determine the configuration of the fenestrations required to preserve these vessels.

The two most common graft designs are (1) a single scallop for an asymmetrically placed renal artery, and (2) two renal fenestrations and a scallop for the SMA.

It is our policy to use uncovered stents if the fabric will make contact with the aortic wall for a few millimeters below the renal artery ostium. If there is no aortic neck below the renal artery, we will plan for a covered stent. Our most common renal stent diameter is 7 mm. It must be remembered that with fenestrated grafts we are typically placing stents in normal renal arteries that often measure ≥ 6 mm. If stents are chosen that are too small, they are likely to dislodge during the procedure.

Once the proximal tubular component of the composite body is planned, then the distal bifurcated component is planned to ensure generous overlap. The distal component is not protected from migration by a barbed anchor stent, and it is a specific design feature that the fenestrated segment is not locked to this distal bifurcated component. This is so the longitudinal distraction force is mainly borne by the distal component, thus minimizing the risk of potentially catastrophic proximal migration. There have been some cases of movement at this modular overlap, which is why a generous overlap of at least three stents is planned. The iliac limbs are planned in the same way as standard endovascular stent grafts. A more detailed review of planning is beyond the scope of this article; however, planning is probably the most important aspect of fenestrated endografting and must be thoroughly understood before undertaking these procedures.

GRAFT DEPLOYMENT

High-quality fluoroscopy is mandatory for the successful deployment of fenestrated grafts. Ideally the procedure will be performed in a fixed angiographic room with operating room–grade sterility. An alternative is to use a high-quality mobile intensifier with a rotating anode and floating carbon fiber operating table. These can be long procedures, and mobile machines with fixed anodes are likely to overheat. Most cases are performed under general anesthesia, although local and regional anesthesia may be used. As with standard endovascular grafting,

options exist for either open exposure of the femoral arteries or percutaneous access with suture-mediated closure on completion.

On the side of delivery of the proximal graft, only one access point is needed. A soft wire is placed in the ascending aorta and then exchanged for a stiff wire such as the 260-cm Lunderquist (Cook, Bloomington, IN). For standard infrarenal endografts, we do not place the guidewire proximal to the aortic knuckle; however, because the fabric is placed higher with a fenestrated graft, it is our practice to place the wire in the ascending aorta to avoid the risk of aortic trauma when the top stent is deployed by pushing off the top cap. On the contralateral side, two points of access are necessary. One is for the imaging catheter and the other for catheterization of the fenestrations and deployment of adjunctive branch vessel stents.

Before introduction the proximal fenestrated component of the composite graft is screened to ensure correct orientation. A thorough understanding of the marker system of the endograft is a key component of success. The correct rotational orientation is determined with reference to the anterior row of vertical and the posterior row of horizontal markers. These should be positioned with overlap to form a cross. A cross may of course be generated in two positions, with the anterior markers either anterior or posterior. The anterior markers can be confirmed to be anterior by rotating the graft under fluoroscopy and confirming that they move in the expected manner with clockwise and anticlockwise rotation. A very useful additional marker is the anterior check mark, which will be reversed if the graft is 180 degrees out of phase. The benefit of this check mark is most apparent in cases where the iliac arteries limit rotation in vivo after graft introduction and there is not a one-to-one torque response.

The correct orientation is also noted with reference to the marginal markers of the renal fenestrations. For example, if the left renal artery is the lowest renal, then the fenestration markers on the left should be the lowest. The graft is thus introduced in the correct orientation over a stiff wire to the correct vertebral level. The vertebral level of the renal arteries can be determined from the CT dataset. The graft may rotate as it is introduced through the iliac arteries, and reorientation may be needed as the graft enters the aorta. It is important to move the graft as one unit and not just rotate one component of the delivery system because this may cause a twist in the graft that is fixed proximally and distally to different components of the delivery system.

An overview angiographic run is performed to mark the renal arteries and aortic bifurcation. A magnified run centered on the renal arteries is then performed. The graft is positioned at the correct height so the fenestrations align with the renal arterial ostia. The

Figure 3 (A) Intraoperative angiogram during fenestrated endovascular aneurysm repair of a juxtarenal aneurysm. (B) Angiography is performed after releasing the first two stents. Manipulation at this stage is usually easy because of the partial deployment and diameter-reducing ties. (C) Completion angiogram shows patent renal arteries and no endoleak.

circumferential orientation is maintained as the graft is part deployed. It is our practice to draw the renal arteries on the monitor screen with a nonpermanent marker. Road maps are often not helpful because the operator needs to study the graft markers continuously as well as the arterial anatomy. Reference images that are faded in and out may be used; however, most operators prefer the apparently technologically backward approach of ink marks on the screen. The first two stents are deployed and then a further angiogram obtained to confirm the position (Fig. 3A–C). Rotation of the graft is still possible at this stage due to the posterior diameter reducing ties. After any required adjustment the proximal component is fully deployed as the position is maintained.

The distal end of the proximal body must now be catheterized from the contralateral femoral artery. This is usually a quick step, although in large aneurysms it may be difficult. Confirmation of successful catheterization is performed and then a stiff wire introduced. It is our practice to introduce a 30-cm-long 20F sheath into the proximal body over this contralateral stiff wire. The proximal body must be held steadily so the position is not altered. The 20F sheath is then used as the parent sheath to allow catheterization of both the renal arteries. An additional sheath through this valve may be required if there is a fenestration for a third renal artery or for the SMA.

Catheterization of the renal arteries is usually achieved with either a Cobra or Berenstein catheter

Figure 4 The anchor stent has been released and the proximal component is now fully deployed. The renal stents will be deployed next.

(Cordis, J & J, Miami Lakes, FL). This should not be a difficult step if the graft is in the correct position. If there are difficulties in catheterization, it is likely due to spontaneous rotation or height change of the endograft. A check angiogram to remark the renal arteries and reposition the graft may be required.

Successful catheterization is confirmed with a small contrast medium injection. This also ensures that inadvertent catheterization of an unintended accessory renal or other neighboring vessel has not been performed. A wire is positioned in a distal renal branch to allow the introduction of a long shaped sheath into the proximal renal artery. Sheaths are placed in both (all) the renal arteries that will be stented and the appropriate stents positioned in these sheaths before further graft deployment. The prepositioning of the renal stents ensures that there is no danger of difficulty tracking stents after full graft release, which could occur if the graft is misaligned. A final angiogram is performed and the graft repositioned if required. The proximal graft is now fully deployed by removing the diameter reducing tie, pushing off the top cap, and releasing the distal graft attachment (Fig. 4). The delivery system of the proximal graft is retrieved, ensuring that the renal sheaths are not dislodged. The ipsilateral sheath is positioned so its proximal extent is in the external iliac artery and internal iliac flow is restored. This is an important step, particularly in long cases, to ensure optimal lower limb perfusion.

The renal stents are now deployed consecutively. The intensifier is angled to profile the origin of the renal artery and the stent positioned so there is ~5 mm protruding beyond the level of the fenestration into the aortic lumen. This aortic portion is subsequently flared with a 10- or 12-mm balloon to allow for easier access if

reintervention is needed at a later date. The proximal section is now completed, and angiography is performed to document renal arterial flow. The renal wires and sheaths are removed and the 20F sheath is moved lower so the contralateral internal iliac artery is perfused.

The distal component of the composite body graft is now prepared and screened. This is a bifurcated piece, and the graft is screened so the contralateral stump is in the correct orientation. The remainder of the procedure is familiar, involving the in vivo assembly of a bifurcated graft with appropriate positioning of the iliac limbs. Care needs to be taken at each stage to avoid wires passing through the interstices of the aortic portion of the renal stents, which could then be dislodged as endograft components are inserted. Contralateral limb catheterization can be confusing because the wire may pass outside the contralateral limb stump but into the proximal body of the endograft, which can lead to false reassurance of successful catheterization.

After complete assembly, the graft overlaps and iliac limbs are inflated with the molding balloon and then completion angiography performed to document seal and branch vessel flow. If there has been a scallop used for the SMA, it is important to observe adequate filling of the SMA and its branches.

SPECIFIC COMPLICATIONS

Several device-specific complications may occur during deployment and in surveillance after fenestrated endovascular aneurysm repair.

During Deployment

Fenestrated stent grafts require precise deployment to align the fenestrations with their target vessels, which requires manipulation at the perirenal level. This undoubtedly increases the risk of renal complications, as does the larger volumes of contrast material that may be used during these procedures. Target vessel stenting also has the potential to cause end-organ damage due to embolization or vessel occlusion. There are patients who have been made dialysis dependent,^{14,15} and there are also reports of bowel ischemia.¹⁶ Fenestration alignment can be more difficult when working within the reduced space of a previous surgical graft or endovascular stent graft to repair anastomotic aneurysms or proximal endoleaks. The increased manipulation further increases the risk of atheroembolization.

Paraostial Endoleak

There is the potential for paraostial endoleaks to occur around the sites of the fenestrations if a seal is not achieved. Covered stents should be used when apposition between the stent-graft fabric and the aortic wall is

expected to be poor. In our own series of 46 patients, we have once had to place a covered renal stent inside an uncovered stent to treat a paraostial endoleak on completion angiography.

Migration

Fenestrations are designed and deployed to be precisely matched up with the ostia of their target vessel. Longitudinal and rotational migration of the stent graft can potentially cause compromise of the targeted vessels, leading to loss. Routine stenting of renal fenestrations is recommended for this reason. Barbs on the bare suprarenal stent improve fixation to resist longitudinal migration. The modular design with overlap also aims to place the drag component of the longitudinal migration forces on the distal bifurcated body, thereby reducing the potential for the fenestrations in the proximal body to migrate. Due to the size of the target vessels, migration of as little as 2 to 3 mm can cause significant compromise, risking target vessel loss. Proximal migration reports are fortunately very rare.

Target Vessel Loss

Target vessel loss has obvious clinical implications. Loss may be due to planning¹⁷ or deployment¹⁶ errors that result in shuttering of the ostium of the target vessel (Fig. 5). Factors associated with target vessel loss in the Australian experience were unstented vessels, > 60 degrees of angulation of the aneurysm neck, multiple renal vessels, and vessels ≤ 4 mm in diameter.¹⁷ The stents that are currently being used to secure fenestrations have not been designed specifically for this purpose. Stents have an important role to play in maintaining alignment of fenestrations, but in the long term they may not be able to resist the longitudinal and rotational migration forces. In our own series we have seen one crushed stent, (Fig. 6) and fractured stents have been seen in other

Figure 5 Postoperative axial computed tomography image. The arrows point to the marginal markers of a scallop for the superior mesenteric artery (SMA). The scallop is not aligned with the SMA ostium, resulting in severe shuttering.

Figure 6 Postoperative surveillance abdominal radiograph shows crushing of the proximal right renal stent.

centers (personal communication). Recent cine CT data has shown significant movement of the renal arteries, which is altered by standard and fenestrated EVAR.^{18,19} The forces acting on these stents are currently unknown but have important implications for the long-term durability of this technique.

Modularity

Although the modular design allows for the proximal component to be the only part of the stent graft that

Figure 7 Computed tomography reconstruction following complex fenestrated endovascular aneurysm repair showing stents in the renal arteries and superior mesenteric artery. The celiac axis remains patent through a scallop in the upper graft. (Image courtesy of Rao Vallabhaneni and generated using the Aquarius Workstation [TeraRecon, San Mateo, CA]).

Table 2 Published Midterm World Experience

	n	Target Vessels	30-Day Mortality	Mean Follow-Up (mo)	Target Vessel Loss	Dialysis
Western Australia ¹⁷	58	116	2	17	10	0
Cleveland Clinic ¹⁴	119	302	1	19	10	4
Netherlands ¹⁶	38	87	1	25.8	7	0
Combined	215	505	4 (1.9%)	20.6	27 (5.3%)	4 (1.9%)

needs to be customized as well as reducing the longitudinal migratory forces on this stented proximal component, there are disadvantages. Component separation can occur resulting in type III endoleaks. Surveillance follow-up with plain radiography is therefore used to look specifically for evidence of component migration, and it allows for timely secondary intervention with an extension cuff.

Follow-Up

Surveillance is required to look for evidence of stent fracture, migration, aneurysm expansion, target vessel patency/stenosis, end organ ischemia and endoleaks. Our current surveillance protocol for patients after f-EVAR incorporates enhanced CT, ultrasound, and plain radiographs (Fig. 7).

PUBLISHED RESULTS

The first reported use of fenestrated grafts was in 1999.⁶ At the Charing Cross International Symposium in April 2006, it was reported that 1000 fenestrated stent grafts had been deployed worldwide. Only three centers have published their midterm results.^{14,16,17} Combining these yields a total of 215 patients with a mean follow-up of 20 months. The 30-day mortality is 1.9%, target vessel loss is 5.3%, and 1.9% of patients have been made dialysis dependent (Table 2). Serum creatinine levels have been used to define and monitor renal dysfunction in almost all the published reports. All the patients that required dialysis from the Cleveland Clinic experience had preoperative renal insufficiency (glomerular filtration rate, < 60 mL/min).¹⁴ There have been no reported late ruptures or conversions to open repair. One patient from the Dutch series required an open laparotomy with repositioning of the stent graft and right renal artery bypass due to endograft malpositioning.¹⁶ In the early Australian experience, several unstented renal fenestrations led to target vessel loss, resulting in the recommendation that all renal fenestrations should be stented.¹⁷

A systematic review by Sun et al²⁰ on the short to midterm outcomes of fenestrated stent grafts, which included six published papers, unfortunately appears to include the analysis of duplicate patients from the Cleveland Clinic and Western Australian series. With

over 1000 fenestrated stent grafts now implanted internationally, this review highlights that less than a third of cases are available for analysis. There are currently no randomized controlled clinical trials and no registry data to aid in the evaluation of this technique.

The safety and efficacy in the short to medium term has been demonstrated. Although the long-term durability and cost effectiveness need to be established, the midterm results appear to justify the continued use and evaluation of this technique as an alternative to open surgical repair for high-risk patients with short-necked and juxtarenal aneurysms.

CONCLUSIONS

The published results of the short term use of fenestrated grafts compare favorably with the results of open surgical repair of juxtarenal aneurysms. Case selection, graft planning, and graft deployment are more complex than with standard endografts. Fenestrated grafts have increased modularity compared with standard three-piece grafts, and movement at modular connections is a risk with time. Migration of the proximal graft is potentially catastrophic because it could cause bilateral renal artery occlusion. Thus far we have seen minimal proximal movement of fenestrated grafts, although a small amount of movement may occur as the barbs of the anchor stent engage. Long-term results are awaited to understand the proper role of fenestrated grafts, which we currently reserve for patients deemed to be at higher than normal risk from open aneurysm repair.

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